United States Department of Agriculture
Agricultural Research Service
Southern Utilization Research and Development Division

THE BRINING AND PICKLING OF CUCUMBERS AND OTHER VEGETABLES

A LIST OF PUBLICATIONS
With Abstracts
September 1938—December 1958
on
COOPERATIVE INVESTIGATIONS
by

U. S. FOOD FERMENTATION LABORATORY
AND
NORTH CAROLINA AGRICULTURAL EXPERIMENT STATION
North Carolina State College
RALEIGH, NORTH CAROLINA

Revised and Edited
by
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Other lists of publications available are:

Improved Cottonseed Meals for Feeding Poultry and Swine

Publications and Patents of the U. S. Citrus Products Station, Winter Haven, Florida

Publications of the U. S. Fruit and Vegetable Laboratory, Weslaco, Texas

Twenty Years of Tung Research

SRRL Publications on Peanuts

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THE U. S. FOOD FERMENTATION LABORATORY

Raleigh, North Carolina

Details of experimental work on the brining and pickling of cucumbers and other vegetables, and results of these studies as carried out in the cooperative research program at the U. S. Food Fermentation Laboratory in Raleigh, North Carolina, have been published in the 63 papers listed herein.

The cooperative pickle research program, conducted jointly by the Agricultural Research Service of the U. S. Department of Agriculture and the North Carolina Agricultural Experiment Station, was initiated in 1935 as an expansion of a study started about two years earlier by the Department of Horticulture of the Experiment Station. The U. S. Food Fermentation Laboratory, located on the campus of North Carolina State College, is a field station of the Southern Utilization Research and Development Division of the Agricultural Research Service, USDA.

Knowledge gained through these investigations has already been given wide application by the commercial pickle industry. This information has enabled packers to put up better products and add new items to their lines. Income to both the cucumber grower and the pickle packer has been increased through greater consumption of pickle products and reduction of losses during the brining and manufacturing operations. Among the most important developments resulting from the Raleigh investigations are: a process for pasteurizing fresh-pack pickles; discovery of the major causes for the softening of commercial salt-stock pickles; and factors responsible for the formation of hollow pickles or "bloaters" both during the brine fermentation of salt-stock and the manufacturing of sweet pickles.

The pasteurization process has made possible both dill and sweet pickles prepared without the usual fermentation and curing in brine. Also, other vegetable products such as peppers, green tomatoes, vegetable relishes and the like are made into fresh-pack pickle products by the pasteurization procedure. The process has also proved advantageous in putting up some types of brine-cured pickle products.

In 1938, approximately 250,000 bushels of pickling cucumbers, representing about 4% of the U. S. crop, went into fresh-pack products, with a return to the farmer of $150,000. In 1955, fresh-pack products accounted for an estimated 3,700,000 bushels, and returned $6,300,000 to the farmer. During that period total consumption of pickles in this country increased from 6,100,000 bushels with a farm level value of $3,600,000, to 13,600,000 bushels with a farm level value of $21,400,000, an increase of about six-fold. Some leaders in the pickle industry are inclined to believe that much of the increase in pickle consumption has come about because fresh-pack (pasteurized) pickles have added new items to the standard pickle line.

Spoilage known as "softening" of commercial cucumber salt-stock causes packers a loss of more thant $1 million each year. Workers at the U. S. Food Fermentation Laboratory have identified two kinds of enzymes, pectinolytic and cellulolytic, as important factors in bringing about this softening. It has been demonstrated that the actual mode of introduction of softening enzymes into the brine is by way of the partially dried, heavily mold laden flowers remaining on the pickling cucumbers. A simple test has been devised to show early in the brining process whether or not the softening enzymes are present, so that steps may be taken to avoid losses from this cause. Practical application of these basic findings has already been made through development of a draining procedure to reduce the amount of softening enzymes present during

brine fermentation, and thus reduce losses to commercial packers. For example, it has been shown that if the original cover brine is drained off the cucumbers 36 hours after filling experimental vats, the softening enzyme content is drastically reduced and the cured stock is firm.

A large-scale experiment on 20 commercial vats (500 bu. capacity) during the 1954 season demonstrated that cured material from 9 drained vats had twice the firmness rating as that from 11 vats brined according to regular plant procedure without draining. In 1955 an estimated 3,000,000 bushels or 1/5 of the total produced received the brine-draining treatment with excellent results as to firmness, quality and color of the stock. In the three years following, 1956 through 1958, approximately 10,000,000 bushels valued at $7,500,000 received the treatment. Savings to Southern processors are estimated at a minimum of $4,000,000 since the initiation of the treatment in 1955. Much greater savings are anticipated as the procedure is adopted by northern and western processors.

Investigations into the causes of bloaters have enabled the Raleigh scientists to offer a number of suggestions for reducing losses of this type.

Research at the U. S. Food Fermentation Laboratory can be grouped under the following broad classifications: chemical and physical; bacteriological; bloater studies; studies on brine-stock firmness; pasteurization; sanitation; cucumber varieties; softening enzymes; and brining and pickling of vegetables other than cucumbers.

I. CUCUMBERS: BRINING AND PICKLING

A. General

1. VELDHUIS, M. K., ETCHELLS, J. L., JONES, I. D., VEERHOFF, O.
NOTES ON CUCUMBER SALTING.
Fruit Prod. J., 20 No. 11, 341-2 (1941).

This article consists of a brief report on the merits of certain brining practices in use at commercial pickle plants. These included the use of sheltered or unsheltered vats, scum control, circulation of brine, painting the inside of vats, and the care of empty vats. The avantages and disadvantages of the various methods studied should prove of benefit to cucumber salters in general.

2. GORESLINE, H. E.
COOPERATIVE PICKLING INVESTIGATIONS OF THE U. S. DEPARTMENT OF AGRICULTURE.
Fruit Prod. J., 21 No. 8, 232-3 (1942).

A brief discussion is given concerning the origin, organization, and general accomplishments of the cooperative pickle work being conducted by the U. S. Department of Agriculture and the North Carolina Experiment Station. The period covered in this article represents the years from 1935 to 1941.

3. ETCHELLS, J. L., and JONES, I. D.
PROGRESS IN PICKLE RESEARCH.
Glass Packer, 30 No. 4, 264-5, 298, 300, 302; 30 No. 5, 358-60, 372, 376, 378, 380 (1951).

Studies from September 1938 to June 1950 reported by the Bureau of Agricultural and Industrial Chemistry of the United States Department of Agriculture and the Department of Horticulture of the North Carolina Agricultural Experiment Station are reviewed. The contributions of this work to the knowledge of commercial brining of cucumbers are discussed under the following broad classifications of studies: Bacteriological studies; pasteurization studies; sanitation; cucumber varietal studies; softening enzyme studies; and wartime studies (1942-1945). A descriptive summary of some of the important findings in each of these fields is given.

4. ETCHELLS, J. L., JONES, I. D., and BELL, T. A.
ADVANCES IN CUCUMBER PICKLING.
Yearbook of Agr. (U. S. Dept. Agr.) 1950-51, 229-36 (Yearbook Separate No. 2195).

This article is a general review of the cucumber pickling industry, and advances which have been made in recent years. The brining process is described, the principal yeasts and bacteria named, and their part in the fermentation process described. Salt-stock spoilage is of two kinds. One is the formation of "bloaters", or hollow cucumbers, and the other is softening of the stock, attributed to

pectin-splitting enzymes which destroy the cucumber tissue. Various types of finished pickle products are made from completely cured salt-stock by leaching out most of the salt, souring with vinegar, and sweetening with sugar. Pasteurization as an important factor in pickle manufacture is discussed. The authors say the ultimate objective of any changes in cucumber pickling is to place this industry among the controlled-fermentation industries. Clearer understanding of fermentation and identification of increasing numbers of microbial groups and their byproducts contributing to the fermentation bring this goal closer.

B. Methods and Procedures

5. VELDHUIS, M. K.
THE PRESERVATION OF BRINE SAMPLES FOR CHEMICAL ANALYSIS.
Fruit Prod. J., 18 No. 1, 6-7 (1938).

A method is given for the preservation of brine samples from cucumber fermentations. This permits taking a large number of samples from fermentations during the green cucumber season and keeping them until chemical analysis can be made at a later date. Ten drops of the chemical, sodium 2, 4, 5, trichlorphenolate, to a pint of brine (1:10,000) dilution is recommended.

6. ETCHELLS, J. L., and GORESLINE, H. E.
METHODS OF EXAMINATION OF FRESH CUCUMBER PICKLE.
Fruit Prod. J., 19 No. 11, 331-5 (1940).

Methods of examination for fresh cucumber pickle are outlined with respect to: (a) bacteriological analyses of pasteurized and unpasteurized pickle, and (b) keeping quality of sealed and open jars of pickle. Unpasteurized pickle underwent fermentation by yeasts and lactic acid bacteria. Pickle pasteurized at 160° F. for 20 minutes (in accordance with the equipment and procedure described) retained its fresh appearance and the major portion of crispness over a storage period of several months.

7. ETCHELLS, J. L., and JONES, I. D.
PROCEDURE FOR PASTEURIZING PICKLE PRODUCTS.
Glass Packer, 23 No. 7, 519-23, 546 (1944).

The pasteurization procedure is discussed in detail together with step-by-step directions for following the rate of heat penetration in various sized containers of pickle. General suggestions and precautions for plant procedure are presented. These deal with the following points: Cleanliness and sanitation; fresh material; handling fresh slices; correct closures; vacuum required; keeping records; container variation; circulation and cooling; and evidence of spoilage.

8. ETCHELLS, J. L., and JONES, I. D.
PROCEDURE FOR BACTERIOLOGICAL EXAMINATION OF BRINED, SALTED, AND PICKLED VEGETABLES AND VEGETABLE PRODUCTS.
Am. J. Public Health, 36, 1112-23 (1946).

Detailed bacteriological methods are given for use in examination of brined, salted, and pickled vegetables and vegetable products. General directions for collection, storage, transportation, and preparation are given for the products as a whole. Individual discussion of the products is presented with respect to: introductory descriptive material; microbial groups involved; significance of observations; and other remarks incidental to the examination. Directions for the preparation and use of differential culture media are combined under a separate section.

9. PETERSON, W. J., BELL, T. A., ETCHELLS, J. L., and SMART, W. W. G.,Jr.
A PROCEDURE FOR DEMONSTRATING THE PRESENCE OF CAROTENOID PIGMENTS IN YEASTS.
J. Bacteriol., 67, 708-13 (1954).

The presence of carotenoid pigments is used in yeast taxonomy to distinguish the genus Rhodotorula from Cryptococcus and Torulopsis genera. Yeast species grown in a synthetic broth for 72 hours on a rotary shaker readily yield pigments from the centrifuged cells by extraction with cold acetone only. The pigments are then transferred to petroleum ether for characterization by chromatographic and spectrophotometric methods. This simple, rapid procedure is aiding in research on yeast species isolated from the flowers of the cucumber plant. Absorption maxima for total carotenoid pigments from 21 species and strains of pigmented yeasts are reported.

10. BELL, T. A., ETCHELLS, J. L., and JONES, I. D.
A METHOD FOR TESTING CUCUMBER SALT STOCK BRINE FOR SOFTENING ACTIVITY.
U. S. Dept. Agr. ARS-72-5, 15 pp. (1955).

The type of spoilage known as "softening" of commercial cucumber salt-stock is a serious problem in the pickle industry. Pectinolytic and cellulolytic enzymes have been identified as causes of such softening. Step-by-step directions for testing commercial cucumber brines for activity of these enzymes early in the brining process are presented in this leaflet. These tests are an improvement over a method previously announced by the same authors, in that less time is required, and tests are given for both cellulolytic and pectinolytic enzymes. Directions are given in easy-to-follow form for quick reference; lists of materials and equipment required, and tables necessary for interpretation of results are included.

C. Bacteriological Studies

11. ETCHELLS, J. L., and VELDHUIS, M. K.
GROWTH OF MYCODERMA SCUM UNDER OIL.
Fruit Prod. J., 18 No. 9, 265-7, 280 (1939).

Utilization by a film-forming yeast associated with pickle scum of the acid and sugar from cucumber brines covered with mineral oil is reported. The results show that although the oil layer did not completely control the destruction of brine acid by the film yeast, a somewhat slower rate of acid utilization was observed when it was used.

12. ETCHELLS, J. L.
INCIDENCE OF YEASTS IN CUCUMBER FERMENTATIONS.
Food Research, 6, 95-104 (1941).

A part of the fermentation of cucumbers in brine is brought about by yeasts, a fact that heretofore has been unrecognized. Active yeast fermentations were found in brining treatments having initial salt concentrations of 5, 7.5, 10 and 15 percent salt by weight (approx. 20, 30, 40, and 60° sal.) A definite correlation was found between brine concentration and the beginning and duration of the yeast fermentation.

13. ETCHELLS, J. L.
A NEW TYPE OF GASEOUS FERMENTATION OCCURRING DURING THE SALTING OF CUCUMBERS.
Univ. Microfilms (Ann Arbor, Michigan), Publ. No. 282, 153 pp. (1941)

Ph. D. thesis, published in bulletin form and abstracted under article No. 15, "The Aerobacter Fermentation of Cucumbers During Salting", Mich. Agr. Sta. Tech. Bull. No. 200, 56 pp. (1945).

14. ETCHELLS, J. L., and JONES, I. D.
BACTERIOLOGICAL CHANGES IN CUCUMBER FERMENTATION.
Food Inds., 15 No. 2, 54-6 (1943).

The predominating microbial groups found in commercial cucumber fermentations during several seasons of study are discussed. A guide to the general relationships in fermentations at 5, 10, and 15 percent salt brine with respect to hydrogen-forming bacteria, acid-forming bacteria, and yeasts is given in table form. The type of fermentation, fermentation activity, chief products formed, and the starting time and duration of fermentation is presented for each group of microorganisms.

15. ETCHELLS, J. L., FABIAN, F. W., and JONES, I. D.
THE AEROBACTER FERMENTATION OF CUCUMBERS DURING SALTING.
Mich. Agr. Expt. Sta. Tech. Bull., No. 200, 56 pp. (1945).

An extensive investigation is presented on the microorganisms responsible for the production of hydrogen in cucumber fermentations. The bulletin is divided into two parts: the first deals with the isolation, identification, and biochemical studies on the responsible organisms; the second part is concerned with the hydrogen and the yeast fermentation of cucumbers under commercial conditions.

16. ETCHELLS, J. L., and JONES, I. D.
CHARACTERISTICS OF LACTIC ACID BACTERIA FROM COMMERCIAL CUCUMBER FERMENTATIONS.
J. Bacteriol., 52, 593-9 (1946).

Identification studies on 49 cultures of lactic acid bacteria occurring during the acid fermentation of salt-stock cucumbers, under conditions typical of the

industry, are reported. The cultures were isolated from actively fermenting brines ranging in salt content from 5 to 12.5 percent by weight. All cultures gave characteristics typical of those described for Lactobacillus planatarum (Orla-Jensen) Bergey et al. and were placed as this species.

17. ETCHELLS, J. L., and BELL, T. A.
FILM YEASTS ON COMMERCIAL CUCUMBER BRINES.
Food Technol., 4 No. 3, 77-83 (1950).

A study of the types of film yeasts found on 40 commercial cucumber brines, ranging in salt content from 5 to 19 percent by weight is presented. The cultures were classified as follows: Debaryomyces membranaefaciens var. Holl., 18 isolates; Endomycopsis ohmeri nov. sp. 12; Endomycopsis ohmeri var. minor, 14; Zygosacch. halomembranis nov. sp. 9; and, Candida krusei (A. Cast.) Four cultures put in the Debaryomyces genus were not placed as to species.

18. ETCHELLS, J. L., and BELL, T. A.
CLASSIFICATION OF YEASTS FROM THE FERMENTATION OF COMMERCIALLY BRINED CUCUMBERS.
Farlowia, 4, 87-112 (1950).

During the 1946 and 1947 brining seasons, 1,444 yeast isolates were obtained from 42 fermenting vats at two commercial pickle plants in eastern North Carolina. The isolates were reduced to species in the following six genera in the order of frequency of isolation: Torulopsis, 721 cultures; Brettanomyces, 588; Zygosaccharomyces, 59; Hansenula, 49; Torulaspora, 6; Kloeckera, 1; and 20 isolates not fully classified. The first two genera named represented a total of 1,309 cultures or slighly over 90 percent of all yeast isolated.

19. BELL, T. A., and ETCHELLS, J. L.
SUGAR AND ACID TOLERANCE OF SPOILAGE YEASTS FROM SWEET-CUCUMBER PICKLES.
Food Technol., 6, 468-72 (1952).

What is believed to be the first preservation-prediction chart for yeast spoilage in sweet-cucumber pickles has been developed through studies of 35 yeast cultures, responsible for gaseous-type spoilage, which were isolated from 15 samples of sweet pickles made by 3 pickle manufacturers in different locations. The yeasts were identified as being closely related to the species Zygosaccharomyces globiformis. The prediction chart should aid the pickle manufacturers in standardizing sweetening formulas, in reducing spoilage, and in saving sugar.

20. ETCHELLS, J. L., COSTILOW, R. N., and BELL, T. A.
IDENTIFICATION OF YEASTS FROM COMMERCIAL CUCUMBER FERMENTATIONS IN NORTHERN BRINING AREAS.
Farlowia, 4, 249-64 (1952)

The yeasts predominating during the fermentation of cucumbers under conditions typical of brining areas in Indiana, Michigan and Wisconsin have been studied.

During three brining seasons (1948-50) 452 yeast isolates were obtained from 155 vat brines collected from 22 individual brining stations, operated by 8 commercial pickle companies. Two species of yeasts occurring during the fermentation were outstanding: Torulopsis holmii and Brettanomyces versatilis. The first yeast predominated during the early period of fermentation (2 to 30 days) and was followed by the second yeast which was most prevalent during the last stage of fermentation (70 to 110 days), but was still present in brines after 12 to 14 months of storage. Between the two extremes in yeast sequence, the species Torulaspora rosei, Hansenula subpelliculosa, and Zygosaccharomyces halomembranis were active.

21. ETCHELLS, J. L., BELL, T. A., and JONES, I. D.
MORPHOLOGY AND PIGMENTATION OF CERTAIN YEASTS FROM BRINES AND THE CUCUMBER PLANT.
Farlowia, 4, 265-304 (1953).

A study of the cellular and colonial morphology of some 30 species of yeasts in 12 genera is presented and profusely illustrated (34 pages of photographs). This publication is the first pictorial study that has been made available of the cultural and morphological characteristics of the yeasts found on cucumbers and in pickle brines.

22. ETCHELLS, J. L., COSTILOW, R. N., BELL, T. A., and DEMAIN, A. L.
CONTROL OF MOLDS DURING THE ENUMERATION AND ISOLATION OF YEASTS FROM SOIL AND PLANT MATERIAL.
Appl. Microbiol., 2, 296-300 (1954).

Three levels of sodium propionate and three levels of diphenyl in acidified dextrose agar and acidified dextrose agar with 5% salt were tested for their ability to restrict mold growth yet permit the rapid growth of yeasts from soil samples. No level of diphenyl tested in acidified dextrose agar inhibited mold growth satisfactorily, and the use of 0.02% of this agent resulted in marked inhibition of the yeasts. Acidified dextrose agar plus 0.35% sodium propionates was the most effective medium tested in separating yeasts from molds in soil samples. However, this chemical, even in low concentrations, greatly inhibited the growth of Endomycopsis ohmeri and completely inhibited Rhodotorula glutinis. Furthermore, the use of propionate agar resulted in very low yeast counts in samples of plant material as compared to the populations obtained with acidified dextrose agar and synthetic agar. Acidified synthetic agar proved to be the medium of choice for the enumeration and isolation of yeasts from plant material.

23. ETCHELLS, J. L., BELL, T. A., and BORG, A. F.
INFLUENCE OF SORBIC ACID ON THE GROWTH OF CERTAIN SPECIES OF YEASTS, MOLDS, AND BACTERIA. (Abstract only)
Bacteriol. Proc. (Soc. Am. Bacteriologists), 55, 19 (1955).

Approximately 200 cultures, representing species in 35 genera of molds, 12 genera of yeasts, and 2 genera of acid-forming bacteria were tested for their ability to grow in liquid media containing sorbic acid. The pH of the culture

medium was found to be the principal factor controlling effectiveness of sorbic acid as an inhibitor of microbial growth. Most cultures grew well at pH 7.0 in media containing 0.1% sorbic acid, whereas at pH 4.5 growth was usually absent. Inhibitory qualities of sorbic acid appear to be directly related to the concentration of undissociated acid.

24. BORG, A. F., ETCHELLS, J. L., and BELL, T. A.
THE INFLUENCE OF SORBIC ACID ON MICROBIAL ACTIVITY IN COMMERCIAL CUCUMBER FERMENTATIONS. (Abstract only)
Bacteriol. Proc. (Soc. Am. Bacteriologists), 55, 19 (1955).

This investigation was undertaken to determine the influence of sorbic acid on the fermentation of large-sized cucumbers brined under conditions typical of industry. Experimental lots with and without 0.1 percent sorbic acid were brined according to the procedure of the cooperating pickle company. In fermentations containing sorbic acid, populations of acid-forming bacteria were reduced tenfold over controls; also, the developed brine acidity was only 0.2 percent as compared to 0.5 percent in control lots. Microbial activity was markedly inhibited in experimental treatments using higher brine strengths. The usual gaseous fermentation caused by brine yeasts was almost completely inhibited by the use of sorbic acid, and "bloater" (hollow stock) spoilage reduced from 60 percent in the controls to less that 5 percent in treated lots. Treated lots were judged to be inferior in cure and color.

D. Chemical Studies

25. VELDHUIS, M. K., and ETCHELLS, J. L.
GASEOUS PRODUCTS OF CUCUMBER PICKLE FERMENTATIONS.
Food Research, 4, 621-30 (1939).

Studies on the composition of the gases produced by commercial cucumber fermentations demonstrated that carbon dioxide was evolved from brines ranging from 5 to 21 percent salt by weight (20 to 80° salometer). Larger volumes of gas were obtained from fermentations at 10 and 15 percent brine strength than at 5, 7.5 and 21 percent strength. Hydrogen was produced in considerable quantities by all fermentations at 15 percent salt. The composition of the gas collected from the interior of "bloaters" (hollow cucumbers) was the same as that evolved from the fermentations from which they were taken.

26. JONES, I. D.
SALTING OF CUCUMBERS: INFLUENCE OF BRINE SALINITY ON ACID FORMATION.
Ind. Eng. Chem., 32, 858-61 (1940).

A three-year study on the influence of brine concentration on acid formation during the fermentation of cucumbers in barrels revealed the following: brines of low salt concentration gave rapid formation of a high amount of acid and a low pH; increasingly higher initial brine strengths (10 to 21 percent) gave correspondingly slower rates of acid formation and lower amounts of acid produced.

27. JONES, I. D., VELDHUIS, M. K., ETCHELLS, J. L., and VEERHOFF, O.
CHEMICAL AND BACTERIOLOGICAL CHANGES IN DILL PICKLE BRINES DURING FERMENTATION.
Food Research, 5, 533-47 (1940).

Various methods of manufacture of dill pickles under southern conditions were tested. The influence of brine concentrations, addition of vinegar, lactic acid, and sugar upon bloater formation, and upon the fermentation as determined by chemical and bacteriological examinations is reported. The percentages of bloaters in large-sized stock (600 count per barrel) for some of the treatments were as follows: control, 20%; 26° sal. brine, 45%; lactic acid added at the start, 67%; sugar added after 1 week, 70%; and sugar added at the start, 78%.

28. VELDHUIS, M. K., ETCHELLS, J. L., JONES, I. D., and VEERHOFF, O.
INFLUENCE OF SUGAR ADDITION TO BRINES IN PICKLE FERMENTATION.
Food Inds., 13 No. 10, 54-6; 13 No. 11, 48-50 (1941)

This paper summarized the results of a series of experiments covering several brining seasons upon the addition of sugar to brines in the manufacture of salt-stock pickles or dill pickles. It is clearly demonstrated that added sugar not only fails to increase brine acidity to a useful degree, but also leads to an increase in the proportion of bloaters in the stock.

29. JONES, I. D., and ETCHELLS, J. L.
PHYSICAL AND CHEMICAL CHANGES IN CUCUMBER FERMENTATION.
Food Inds., 15 No. 1, 62-4 (1943)

Physical and chemical observations on cucumber fermentations covering several brining seasons are summarized. It was found that the use of low salt content brines, during the first five days of curing, favors rapid acid development and the production of a comparatively large amount of acid, with only a small amount of gas. However, high salt content brines retard the rate of acid formation, reduce the amount formed, and favor a gaseous fermentation and bloater formation.

30. PETERSON, W. J., EVANS, W. R., LECCE, EILEEN, BELL, T. S., and ETCHELLS, J. L.
QUANTITATIVE DETERMINATION OF THE CAROTENOIDS IN YEASTS OF THE GENUS RHODOTORULA.
J. Bacteriol., 75, 586-91 (1958).

Methods have been developed for the characterization and quantitative analysis of carotenoids present in species of the genus Rhodotorula. The pigments in hexane, obtained from cells grown and extracted as reported previously, were extracted with 90% methanolic potash (0.1N) and the alkali-soluble torularhodin determined by the difference in absorption of the hexane solution at 500 mu, before and after extraction. Aliqots of the extracted hexane were then chromatographed on columns of MgO-Supercel (2:1) and developed with 95% ethanol. Beta-carotene and gamma-carotene were eluted completely with the ethanol and their respective concentrations determined from readings at critical wave

lengths using formulae customarily used for the colorimetric analysis of two-component color systems. The strongly adsorbed torulene was determined from the difference in absorption at 484 mu, before and after chromatography. The relative quantities of torularhodin, torulene, beta-carotene and gamma-carotene, respectively, in each of four Rhodotorula species were as follows (in % of total pigment): R. glutinis: 66.8, 27.2, 3.5, and 2.3; R. glutinis var. rubescens: 29.8, 37.8, 23.9, and 8.5; R. rubra: 49.3, 27.5, 14.6, and 8.5; and R. mucilaginosa: 28.6, 59.3, 9.0, and 3.1. Mean yields of total pigment from the four species were (in ug. per gram of dry cells): R. glutinis 332; R.. glutinis var. rubescens 494; R. rubra 187; and R. mucilaginosa 358.

E. Bloaters (Hollow Cucumbers)

31. JONES, I. D., ETCHELLS, J. L., VEERHOFF, O., and VELDHUIS, M. K.
OBSERVATIONS ON BLOATER FORMATION IN CUCUMBER FERMENTATION.
Fruit Prod., J., 20 No. 7, 202-6; 219-20 (1941).

Observations are presented with reference to the nature of proportion of bloaters (hollow cucumbers) formed in cucumbers receiving different curing treatments. It was concluded that bloater formation is related to a gaseous fermentation. Factors which favor the development of a vigorous gaseous fermentation (additons of sugar, lactic acid, or acetic acid in sufficient amounts, or strong brines) favor the production of bloaters.

32. ETCHELLS, J. L., and JONES, I. D.
AN OCCURRENCE OF BLOATERS DURING THE FINISHING OF SWEET PICKLES.
Fruit Prod. J., 20 No. 12, 370,281 (1941).

Bloater formation as reported in this case was attributed to the fact that the pickles were finished at too low an acidity. The chemical and bacteriological analyses of the fermented liquor, together with the analysis of the gas from the bloaters, indicated that yeasts were responsible for the spoilage involved.

33. ETCHELLS, J. L., JONES, I. D., and BELL, T. A.
YEASTS: BRIGANDS IN BRINE
Research and Farming (N. Carolina Agr. Expt. Sta.), 10 No. 1, 3-4(1951).

The formation of bloaters (hollow cucumbers) during pickle brining causes an estimated loss of about one million dollars annually. This article briefly summarizes the work of authors on this problem and points out that the gaseous fermentation caused by yeasts is responsible for most bloater formation. Yeast colonies and yeast cells are illustrated in the article together with brined cucumbers that have undergone typical bloater damage by yeast activity.

F. Pasteurized Pickles

34. ETCHELLS, J. L., OHMER, H. B., and JONES, I. D.
PASTEURIZED PICKLES?
Research and Farming (N. Carolina Agr. Expt. Sta.), 10 No. 2, 11 (1951).

A one page general non-technical article dealing with pasteurized pickles.

35. ETCHELLS, J. L.
RATE OF HEAT PENETRATION DURING THE PASTEURIZATION OF CUCUMBER PICKLE.
Fruit Prod. J., 18 No. 3, 68-70 (1938).

The pasteurization of fresh cucumber pickle (sweet slices) was studied with particular emphasis placed on the rate of heat penetration to the center of glass jars of pickle, and the rate of heat loss during the subsequent cooling. Under the commercial conditions used, and with a batch operation, the water and jars reached 160° F. in about 30 and 60 minutes, respectively. The cooling operation was accomplished in approximately 25 minutes.

36. JONES, I. D., ETCHELLS, J. L., VELDHUIS, M. K., and VEERHOFF, O.
PASTEURIZATION OF GENUINE DILL PICKLES.
Fruit Prod. J., 20 No. 10, 304-5, 316, 325 (1941).

The work demonstrates the desirability of pasteurizing genuine dill pickles to retain their firmness during storage. Dills which received pasteurizing treatments amounting to a maximum internal pickle temperature of 140, 160, and 167° F. retained a satisfactory degree of firmness for storage periods of a year to 16 months. This was in contrast to unpasteurized lots which rapidly became so soft that they were unusable.

37. ETCHELLS, J. L., and OHMER, H. B.
A BACTERIOLOGICAL STUDY OF THE MANUFACTURE OF FRESH CUCUMBER PICKLE.
Fruit Prod. J., 20 No. 11, 334-7, 357 (1941)

The results of a routine bacteriological study of the manufacture of pasteurized, fresh cucumber pickle, under commercial conditions, and covering a four-year period (1937-1940) are reported. The findings showed that only the heat-resistant, spore-forming bacteria survived the pasteurizing procedure (160° F. for 20 minutes or 165° F. for 15 minutes) and that these organisms showed little or no increase during storage of the pickle.

38. ETCHELLS, J. L., and JONES, I. D.
PASTEURIZATION OF PICKLE PRODUCTS.
Fruit Prod. J., 21 No. 11, 330-2 (1942)

Pickle products requiring pasteurization during their manufacture have been

placed in three general classes: namely unfermented, partially fermented, and fully fermented. Typical examples of products in each of these classes have been investigated with respect to the use of a uniform pasteurization procedure in all cases: namely, an internal product temperature of 165° F. for 15 minutes followed by prompt cooling. The results demonstrate that the organisms responsible for fermenting or otherwise deteriorating the products were killed. Also, most of the original crispness or firmness of the products was retained over a reasonably long storage period.

39. ETCHELLS, J. L., and JONES, I. D.
MORTALITY OF MICROORGANISMS DURING PASTEURIZATION OF CUCUMBER PICKLE.
Food Research 8, 33-44 (1943).

The results of a series of experiments dealing with the mortality of microorganisms during the pasteurization of cucumber pickle are presented. Procedures using temperatures of 120, 130, 140, 150, and 160° F. for 15 minutes were employed for pickle inoculated with acid-forming bacteria and yeasts as the test organisms. The pasteurizing treatment using 160° F. was sufficient to kill both acid-forming bacteria and yeasts in all pickle liquors used, irrespective of the quantity of inoculum employed.

40. ETCHELLS, J. L., and JONES, I. D.
THE IMPORTANCE OF CARE IN THE PASTEURIZATION OF PICKLE PRODUCTS.
Canner, 98 No. 9, 28, 64 (1944).

The nature of the pasteurization procedure for pickles is discussed briefly and attention is directed to the cause of pasteurization failures in commercial pickle plants. The importance of keeping records, checking the course of heating, proper cooling, container size, and adequate headspace in containers, are some of the points emphasized in connection with the pasteurizing process.

G. Softening Enzyme Studies

41. BELL, T. S., ETCHELLS, J. L., and JONES, I. D.
SOFTENING OF COMMERCIAL CUCUMBER SALT-STOCK IN RELATION TO POLYGALACTURONASE ACTIVITY.
Food Technol., 4, 157-63 (1950)

A sensitive method is described for detecting a pectin-splitting enzyme in commercial cucumber brines. The enzyme compares similarly in chemical behavior to polygalacturonase and has been found present in cucumber brines from various brining areas and correlated with softenting of the salt-stock.

42. BELL, T. A., and ETCHELLS, J. L.
PECTIN HYDROLYSIS BY CERTAIN SALT-TOLERANT YEASTS.
Appl. Microbiol., 4, 196-201 (1956).

A total of 143 yeast cultures, representing 66 species and varieties in 15 genera, were investigated by use of a simplified screening technique for their ability to hydrolyze citrus pectin in culture media as indicated by de-esterification and glycoside hydrolysis. Species and varieties in the following 7 genera were able to de-esterify citrus pectin; Debaryomyces, 8 species; Candida, 4; Endomycopsis, 2; Hansenula, 3; Rhodotorula, 2; Zygopichia, 1; Torulopsis, 1; and unidentified, 3. Only 4 of the 143 cultures gave clear-cut tests for glycosidic hydrolysis. They were: Saccharomyces fragilis, Saccharomyces fragilis var., Saccharomyces species (Hall) from citrus concentrate, and unidentified yeast Y-659. All came from sources other than cucumber brines.

43. BELL, T. A.
PECTOLYTIC ENZYME ACTIVITY IN VARIOUS PARTS OF THE CUCUMBER PLANT AND FRUIT.
Botan. Gaz., 113 No. 2, 216-21 (1951).

The cucumber plant and fruit (Cucumis sativus L.) have been found to be a source of a pectolytic enzyme as measured by a loss in viscosity of a pectin solution. The enzyme of the cucumber was strongly active in the seeds, staminate and pollinated pistillate flowers, and ripe fruit, but was not found in the unpollinated flowers, leaves, petioles, and stems. Enzyme activity was weak to negative in the eight stages of cucumber development of immature fruit. Pectolytic enzyme activity was absent in the green tomato (Lycopersicon esculentum) including the embryo with flowers and six stages of green-fruit development. High activity of the enzyme was found in the red ripe tomato fruit.

44. BELL, T. A., ETCHELLS, J. L., and JONES, I. D.
PECTINESTERASE IN THE CUCUMBER.
Arch. Biochem. Biophys., 31 , 431-41 (1951).

Pectinesterase, the de-esterifying pectic enzyme, has been found in the seeds, leaves, petioles, stems, flowers and fruit of the pickling cucumber (Cucumis sativus L.). In the cucumber fruit, the enzyme content remains fairly constant throughout fruit development, but in the tomato fruit (Lycopersicon esculentum) it increases very rapidly, to over 300 times the initial amount. The low esterase content of commercially brined cucumbers was attributed chiefly to inactivation of the enzyme by the acid resulting from the lactic fermentation.

45. ETCHELLS, J. L., BELL, T. A., and JONES, I. D.
CUCUMBER BLOSSOMS IN SALT-STOCK MEAN SOFT PICKLES.
Research and Farming, 13 Nos. 1-4, 14-5 (1955).

Softening of cucumbers during brining causes large losses to commercial pickle packers annually. Studies carried out by the authors indicate that such softening is caused by the action of pectin-splitting enzymes on the tissues of the cucumbers, and further studies indicate that blossoms retained on the cucumbers during brining are a potent source of pectin-splitting activity. Several different approaches to a solution of the problem are suggested.

46. ETCHELLS, J. L., BELL, T. A., and JONES, I. D.
STUDIES ON THE ORIGIN OF PECTINOLYTIC AND CELLULOLYTIC ENZYMES IN COMMERCIAL CUCUMBER FERMENTATION.
Food Technol., 9 No. 3, 14, 16, (1955). (Published as long abstract only).

Results of studies during the past three years appear to indicate molds are potent sources of enzymes responsible for softening-type spoilage of commercially brined cucumbers, and that the enzymes are introduced into the brine by way of heavily mold-laden cucumber flowers which remain attached to the fruit. Samples from vats containing a high percentage of flowers were shown to contain high enzyme activity, and in general the salt-stock was either soft or inferior in firmness. When flowers were removed before brining, samples were very low in enzyme activity and cured stock exceptionally firm. Identification studies, in cooperation with mycologists at Harvard University, are being completed on more than 1,000 cultures of molds from flowers, ovaries and fruit. Results to date reveal species belonging to about 40 genera and families of molds. Of total isolations, 92% have the ability to destroy pectin in cultural media.

47. BELL, T. A., and ETCHELLS, J. L.
PECTINASE INHIBITOR IN GRAPE LEAVES.
Botan. Gaz., 119 No. 3, 192-6 (1958).

A water-soluble substance in grape leaves which inhibits purified polygalacturonase and also pectinase from mold-laden cucumber flowers is reported. Of the six grape varieties tested, the leaves from Scuppernong of the Muscadine group (Vitis rotundifolia Michx.) contained the highest concentration of the inhibitor. The other grape varieties tested, listed in the decreasing order of inhibitor concentration were: Sheridan, Concord, Niagara, Portland, and Leutie (all varieties of Vitis labrusca L.). The inhibiting substance in the crude grape leaf extract was stable to heat, non-dialyzable through cellophane membrane against water, and could not be completely precipitated with acetone or ammonium sulfate. The reduction in pectinase activity obtained was directly related to the inhibitor concentration used. The reaction between polygalacturonase, the substrate, and the inhibitor was that of competitive inhibition.

48. BELL, T. A., ETCHELLS, J. L., and COSTILOW, R. N.
SOFTENING ENZYME ACTIVITY OF CUCUMBER FLOWERS FROM NORTHERN PRODUCTION AREAS.
Food Research, 23, 198-204 (1958).

During August 1955, a total of 19 samples of retained cucumber flowers from No. 1 size (1 to 1-1/16" dia.) stock were collected at 17 brining stations and one receiving station located in Michigan, Wisconsin, Indiana, and Ontario. Eight additional samples, representing freshly opened flowers were removed from cucumber ovaries in 8 fields located in Michigan and Wisconsin. All samples were immediately frozen with dry ice and kept in this condition until tested for enzyme activity. The pectinolytic enzyme activity of the station flowers ranged from 31 to 308 softening units (av. 120) calculated on a per flower basis (av. wt. 0.0238 g.); the field flowers ranged from 350 to 1,737 units per flower (av. 875). The average weight of a freshly opened field flower

was found to be 0.281 g.; this was about 12 times the weight of an individual partially dried flower removed from No. 1 size stock at brining stations. Considering all samples collected from each source (brining stations and fields), the flowers removed from ovaries in the fields had about seven times more pectinolytic activity than those removed from No. 1 size cucumber fruit being delivered to the brining station. For cellulolytic enzyme activity, considering all field flowers, the range was 102 to 221 units (av. 151); for brining station flowers, 213 to 2,199 units (av. 680). This represented an average increase in cellulase activity of about four and one-half times for station flowers as compared to field flowers. This was somewhat the reverse of the situation for pectinase activity. These results indicate that cucumber flowers from northern production areas can possess a potential softening enzyme activity which, if introduced into curing vats in sufficient amounts under suitable conditions, could destroy the firmness of brined material in a manner previously demonstrated for cucumbers brined under southern conditions.

49. ETCHELLS, J. L., BELL, T. A., and WILLIAMS, C. F.
INHIBITION OF PECTINOLYTIC AND CELLULOLYTIC ENZYMES IN CUCUMBER FERMENTATIONS BY SCUPPERNONG GRAPE LEAVES.
Food Technol., 12, 204-8 (1958).

The pectinolytic and cellulolytic enzymes of cucumber flowers, when added to small-scale cucumber fermentations, were effectively reduced in activity by the use of a crude extract of Scuppernong grape leaves (Vitis rotundifolia). There was no apparent influence on the grape leaf inhibitor on the character of the acid fermentation as measured by total brine acidity, pH, and optical density of the brine. The reduction in activities of the two enzyme systems added to the cucumber fermentations was directly related to the inhibitor concentration used. Higher levels of inhibitor resulted in increasingly higher firmness ratings of cured, salt-stock cucumbers. In general, the judges at the pickle plant rated the salt-stock Good to Excellent as to Acceptability for Commercial use.

50. ETCHELLS, J. L., BELL, T. A., MONROE, R. J., MASLEY, P. M., and DEMAIN, A. L.
POPULATIONS AND SOFTENING ENZYME ACTIVITY OF FILAMENTOUS FUNGI ON FLOWERS, OVARIES AND FRUIT OF PICKLING CUCUMBERS.
Appl. Micobiol., 6, 427-40 (1958).

Results are presented for a study on populations of filamentous fungi occurring on samples of flowers, ovaries and fruit of the cucumber plant (Cucumis sativus L.) throughout one growing season, pectinolytic enzyme activity of such cucumber material, and pectinolytic and cellulolytic enzyme activity of representative fungus species isolated in the course of the investigation. During the four-to-six-week harvest season, rather high fungus populations and accompanying pectinolytic enzyme activity were obtained for certain samples of cucumber material. This was especially true for flowers collected from fields and those removed from fruit at the brining station. The latter, because they are introduced into the vats with the fruit that is brined, were considered a potent source of softening enzymes. Representative isolates of the various species of fungi isolated from cucumber material were tested for their action on pectin and

cellulose; of the 73 species in 34 genera obtained, most proved to be both pectinolytic and cellulolytic. This was particularly true for the 10 most frequently isolated species which represented almost 75% of the total isolations (1032). The studies reported definitely implicate filamentous fungi as the actual causative agent responsible for softening spoilage of cucumbers brined under conditions typical of the South. Further, it is believed that softening enzyme systems are introduced into the curing brines chiefly by way of the fungus-laden flowers that remain attached to the cucumbers, and to a lesser extent by the fruit itself.

H. Varieties for Pickles

51. JONES, I. D., and ETCHELLS, J. L.
CUCUMBER VARIETIES IN PICKLE MANUFACTURE.
Canner, 110 No. 1, 34, 36, 38, 40 (1950).

Tests were conducted in several important pickle packing areas in the southern states with both the newer and the older pickling varieties. These studies included: storage tests on fresh material; preparation of sweet pickle and pasteurized dills; and examination of salt-stock. It was found that wide differences in product quality occurred, and that these differences were associated with varietal characteristics.

52. JONES, I. D., ETCHELLS, J. L., and MONROE, R. J.
VARIETAL DIFFERENCES IN CUCUMBERS FOR PICKLING.
Food Technol., 8, 415-8 (1954).

The suitability of 19 varieties and strains of cucumbers for salt-stock production were evaluated over a 3-year period at a commercial pickling plant. Differences of a magnitude considered commercially important are reported.

I. Sanitation for Factories

53. ETCHELLS, J. L.
SUGGESTIONS REGARDING PICKLE PLANT SANITATION.
Fruit Prod. J., 26 No. 2, 45-8, 58 (1946).

The discussion of pickle plant sanitation is presented to serve as a guide and as suggestions for the National Pickle Packers Association. The material is organized on the basis of suggestions concerning: Premises, Manufacturing Practices, Personnel, and Methods of Analysis. It is pointed out that the progressive pickle packer can readily meet the reasonable and just sanitary obligations required by law irrespective of his locality. As to those who are less progressive, it hardly seems a matter of what they want to do, but rather what is expected of them in the best interests of the customer.

II. OTHER VEGETABLES: BRINING AND PICKLING

A. General

54. ETCHELLS, J. L., and JONES, I. D.
COMMERCIAL BRINE PRESERVATION OF VEGETABLES.
Fruit Prod. J., 22 No. 8, 242-6, 251, 253 (1943).

A general report of a war-time study on the brine preservation of certain vegetables is given. Included in the study were green snap beans, green peas, lima beans, yellow wax beans, carrots, and certain leafy vegetables, such as turnip greens, mustard greens and kale. Recommendations for the routine brining of the vegetables investigated are included. Vitamin retention with respect to carotene (pro-vitamin A) and vitamin C is reported for certain of the vegetables brined.

55. ETCHELLS, J. L., JONES, I. D., and HOFFMAN, M. A.
BRINE PRESERVATION OF VEGETABLES.
Proc. Inst. Food Technologists, 176-82 (1943).

The results on the brining of various types of vegetables is presented in connection with the over-all possibilities of brine preservation as an emergency method for storing foods. The experiments demonstrate that brine preservation methods based on different degrees of refinement may be satisfactorily employed for storing large quantities of vegetable material in bulk until further processing can be carried out.

B. Methods and Procedure

56. ETCHELLS, J. L., and JONES, I. D.
PRESERVATION OF VEGETABLES BY SALTING OR BRINING.
U. S. Dept. Agr. Farmers' Bull. No. 1932, 14 pp. (September 1943, rev. June 1944).

Salting or brining is a good way to preserve vegetables, especially when they cannot be frozen or canned. The method is inexpensive and not difficult for home use. Sauerkraut, made by salting cabbage, is well known and widely used. This bulletin tells how to put up a number of other vegetables besides cabbage.

C. Bacteriological Studies

57. ETCHELLS, J. L., JONES, I. D., and LEWIS, W. M.
BACTERIOLOGICAL CHANGES DURING THE FERMENTATION OF CERTAIN BRINED AND SALTED VEGETABLES.
U. S. Dept. Agr. Tech. Bull. No. 947, 64 pp. (October 1947).

In most instances, microbial activity of varied intensity accompanied vegetable

preservation by salting or brining, and was present over a wide range with respect to both the type of vegetable and the amount of salt used. The predominating groups of microorganisms found were: the acidforming bacteria, the coliform bacteria, the yeasts, and the coccus forms. The influence of salt concentration upon the above microbial groups is discussed. The bulletin contains an appendix which describes in detail the bacteriological media and methods used in the work.

D. Nutritive Value

58. JONES, I. D., and ETCHELLS, J. L.
NUTRITIVE VALUE OF BRINED AND FERMENTED VEGETABLES.
Am. J. Public Health, 34, 711-8 (1944).

The results demonstrate that certain vegetables which are important sources of proteins, starches, and minerals are well adapted to brine preservation and can be used as non-pickle products. Furthermore, it was shown that these constituents are well retained in such brine preserved vegetables. The greatest conservation of nutrients is accomplished by using the brined material without desalting, such as in the preparation of soups or certain vegetable mixtures.

59. JONES, I. D., and ETCHELLS, J. L.
FOOD VALUE OF BRINED VEGETABLES.
Research and Farming, 4 No. 1, 1-2, 12 (1945).

This is a popular revision of the paper which appeared in the Am. J. Public Health, 34, 711-8 (1944), and is abstracted above (No. 58) under the title "Nutritive Value of Brined and Fermented Vegetables."

III. MISCELLANEOUS

A. Silage Studies

60. NORTH CAROLINA AGRICULTURAL EXPERIMENT STATION AND BUREAU OF AGRICULTURAL AND INDUSTRIAL CHEMISTRY (USDA)
SWEET POTATO VINE SILAGE
N. Carolina State Coll. Agr. Expt. Sta. Circ. No. 3, 3 pp. (October 1944).

This circular describes briefly how to make silage from sweet potato vines.

61. ETCHELLS, J. L., and JONES, I. D.
BACTERIOLOGICAL CHANGES DURING THE FERMENTATION OF STEAMED POTATOES FOR SILAGE.
J. Agr. Research, 78, 19-31 (1949).

The results of a bacteriological examination of the fermentation hot-ensiled

steamed potatoes (Solanum tuberosum) are reported. The findings demonstrate that the thermophilic, facultative anaerobes were the predominating microorganisms present during the fermentation and were responsible for the developed acidity and resultant preservation of the silage. These organisms may be classified according to Bergey et al., as thermophiles belonging in Group X of the genus Bacillus.

62. HALL, H. H., ETCHELLS, J. L., JONES, I. D., and LEWIS, W. M.
MICROBIOLOGICAL AND CHEMICAL STUDIES OF SWEET POTATO VINE SILAGE.
J. Dairy Sci., 37, 1325-36 (1954).

Sweetpotato vines and combinations of vines, tubers, and molasses were ensiled during consecutive years in glass jars and wooden barrels. There resulted under each condition an acid-type fermentation with the production of silage having good odor, color, and texture. During the most active phase of fermentation, the population of acid-forming bacteria, which was mainly L. plantarum, increased rapidly from 150 to 600 million per gram of silage in about 5 days. Although the population of acid-forming bacteria varied from year to year, their numbers were not greatly influenced by the addition of sweetpotato tubers or molasses to the vines. Chemical changes during the fermentation were evidenced by a drop in pH, a decrease in the sugar content, and the formation of lactic acid. The addition of tubers and molasses to vines increased the amount of acid formed, over vines alone, except one year when low temperatures prevailed throughout the active fermentation phase. Analysis of data on techniques shows different sources of experimental error; i.e., 6% for plating and counting, 50% for samples taken within a barrel, and 15% for samples from barrels with the same treatment.

B. Yeasts from Meat Brines

63. COSTILOW, R. N., ETCHELLS, J. L., and BLUMER, T. N.
YEASTS FROM COMMERCIAL MEAT BRINES.
Appl. Microbiol., 2, 300-2 (1954).

A total of 89 yeast isolates, all belonging to the genus Debaryomyces were obtained from nine casks of commercially brined meat. Seventy of the isolates came from surface films on the brines and 19 from subsurface brine samples. Eighty-six of the cultures were identified as Debaryomyces membranaefaciens var. Hollandicus Lodder and were responsible for film formation on the brines. The remaining three cultures were placed as Debaryomyces klockeri Guill. et Pe'ju. These isolates were nonfilmforming and were isolated from subsurface brine samples.

AUTHOR INDEX
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